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To Mr. F.J. Kee
Director of Research

FAULT ANTICIPATION SYSTEM FOR SUBSTATION EQUIPMENT - FINAL REPORT

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An on-line partial discharge detection and monitoring system has been developed for deployment on high voltage equipment in a substation. The objective of the system is to identify approaching failure for station operators without giving any false alarms. Positive indication of imminent failure has been demonstrated, as well as immunity to noise due to atmospherics, disconnect operations, or from other common sources.

INTRODUCTION

Studies on both epoxy and oil-paper high voltage insulation systems as well as experience in the field have indicated that failure in such systems is nearly always preceded by the generation of high magnitude partial discharge (pd) pulses for times ranging from several minutes to hours or even days /1,2,3,4/. On-line monitoring of the partial discharge level in high voltage equipment has resulted in significant benefit to Ontario Hydro in the case of rotating machines/1/ and metalclad switchgear/5,6/. Experience gained in the processing of partial discharge pulse data in these contexts, suggested the possibility of unequivocally identifying such a source in a substation environment. Knowing that a particular piece of equipment, such as a CT, was potentially in trouble/7/, the station operator could take corrective action to deenergize and isolate the unit thus preventing a possible explosion with potential hazard to personnel and other equipment. In case of too short a warning time the operator could immediately identify a failed unit, minimizing unnecessary switching.

job	file	date	report no.
740615-512-333	811.4	October 28, 1985	85-215-K

FAULT ANTICIPATION FOR STATION EQUIPMENT (FASE)

A system has been developed and successfully tested that is simple, inexpensive and may readily be retrofitted in existing stations. The principle of the monitoring equipment, circuit details and pulse propagation and attenuation tests on station diameters, etc. have been fully described in earlier reports /8,9,10,11/ and will only be briefly recalled here.

Individual noise (voltage) pulses on a station diameter will be common to and have the same polarity for all pieces of equipment on that diameter. However, the current pulse resulting from a partial discharge originating at a potential breakdown site in any one unit will have a particular polarity through the ground lead, and it will return to the discharge site through the ground leads of all other devices on the diameter, but with the opposite polarity.

Discharge detection units (DDU) fed from ferrite split-core RF CT's may be easily applied to the ground leads of each piece of monitored equipment. These units convert discharge pulse polarity data to a digital signal, and an electronic translation device at a central location determines digitally that the pulse polarity for one and only one input from a selected diameter is opposite to every other input for (at least three) units being monitored, and identifies the suspect unit. If all pulse polarities are in the same direction, as for a noise situation, or if not all inputs are activated (within the expected time of travel of a pulse along the diameter) the monitor responds appropriately /14,15,16/. In this way the system can rapidly identify failing equipment, without false alarms.

EQUIPMENT EVALUATION

A prototype equipment/14,15,16/ designed to monitor six CTs or PTs was evaluated in the laboratory, and after successful operation was demonstrated /10/, field installations on 230 kV CT's were activated at several locations /11,12/. No "false alarms" were received in the field environment, however because no CT failed, there was no positive demonstration of successful fault anticipation.

Accordingly six surplus 230 kV CT's were installed at the Kleinburg test site fitted with DDU's and energized to 150 kV phase-to-ground, Figs 1,2. The insulation on one unit was weakened in an attempt to precipitate a failure, but months passed with no indication of the beginning of breakdown until the unit failed suddenly while the FASE equipment was inoperative. Finally it was decided to install an artificial pd source on the bushing of one of the CT's in such a manner that the discharge pulses would travel through the ground lead. This was accomplished by wrapping a strip of aluminum foil around the bushing beneath about the fourth skirt above ground, and connecting a spark plug from the foil to the CT case. The pd current through such a high impedance (low capacitance source) is estimated to be far lower than might be expected between say two bushing capacitor foils. The FASE monitor indicated the "faulty" unit correctly in the presence of considerable bus noise.

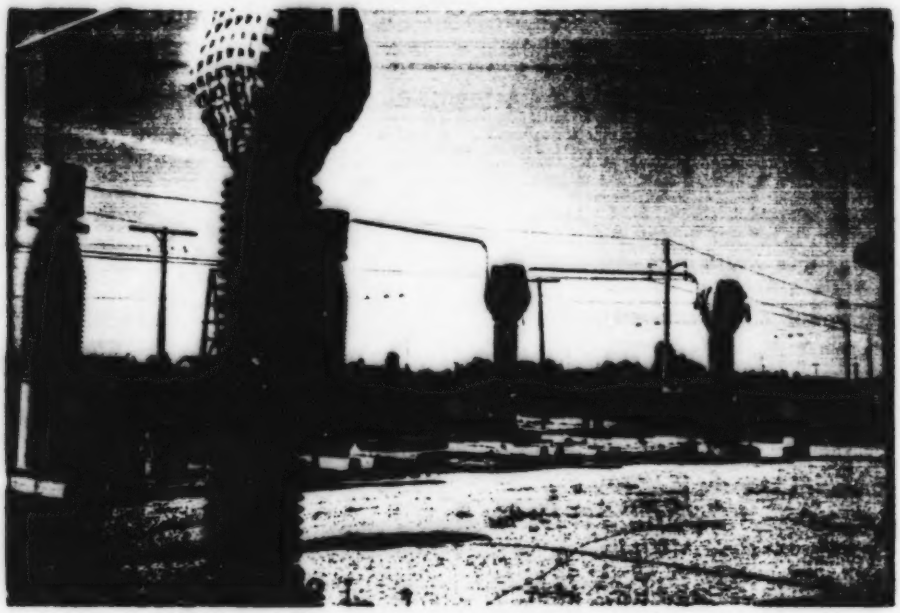

Figure 1. 230 kV CT's at Kleinburg for Final FASE Demonstration Tests

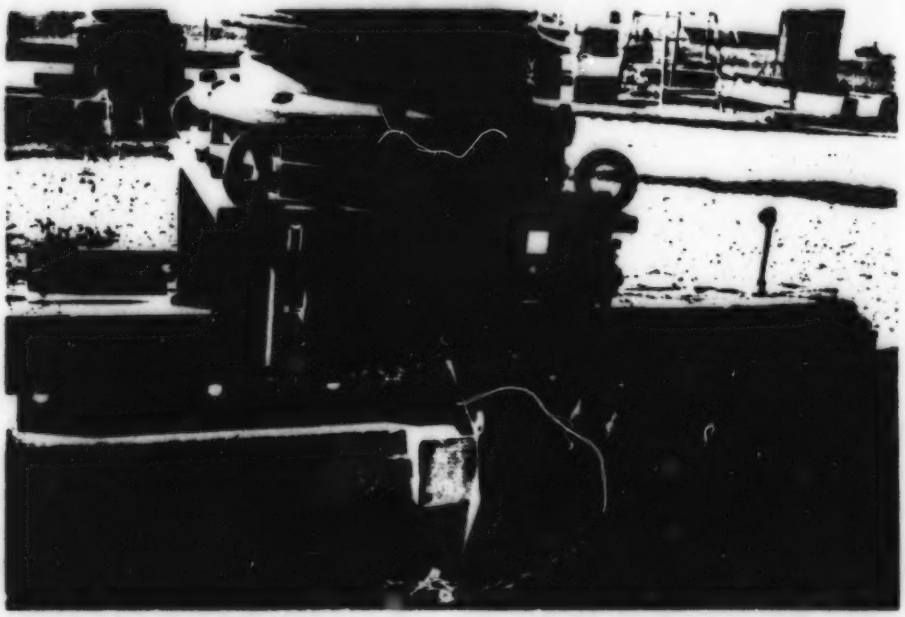

Figure 2. DDU on Ground Lead of a 230 kV CT

CONCLUSIONS AND RECOMMENDATIONS

1. The principle of circuitry capable of rejecting noise and monitoring pd on HV equipment in a noisy environment has been demonstrated; the onset of pd and its increase with time, may be taken as a certain indication of impending failure.

2. "Field-hardened" equipment incorporating fiber-optic isolation should be developed and installed on the diameters in a least two stations for up to two years of field evaluation under operational conditions.

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15. U.S. Patent No 4385271

16. European Patent Applied For No 82301201.8-2204